Codes and Standards Enhancement Initiative
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Proposed Energy Efficiency Specifications for General Service Incandescent Lamps
[Corrected from June 22, 2005 Version]

Prepared for:
Gary B. Fernstrom, PG&E

Prepared by:
Ecos Consulting

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The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports and supporting documentation that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards.

The California Energy Commission (CEC) adopted Tier 1 energy efficiency standards for soft white and clear/frosted general service incandescent lamps in December 2004. Those standards will take effect in January 2006, and aim for an average efficiency improvement of approximately 3.6%. This document addresses proposed Tier 2 energy efficiency standards for those product categories, while also proposing a comparable level for "enhanced spectrum" lamps not currently regulated by the CEC.

This analysis updates the original PG&E CASE report on general service incandescent lamps in three key ways: new product catalog data, new krypton research, and new proposed specification lines. First, Ecos Consulting returned to the current web-based product catalogs of each of the major lamp manufacturers to obtain current data on lamp lumens, wattage, and lifetime. Those catalogs are available on the following websites:

General Electric:
http://www.gelighting.com/na/business_lighting/education_resources/literature_library/catalogs/lamp_catalog/

Osram Sylvania:
http://www.sylvania.com/ProductCatalogs/LampandBallastProductCatalog2004/

Philips:
http://www.topbulb.com/find/philips.asp

Feit:
http://feit.com/household.html

Westinghouse:
http://www.westinghouselightbulbs.com/bulbfinder_results.php?pl=cs-i

Second, Ecos reviewed the existing technical literature for estimates of the energy efficiency benefits achievable through the use of a krypton fill gas instead of argon. Two papers provided particular detail on the subject:

W.E. Thouret, R. Kaufman, and J.W. Orlando, "Energy and cost saving krypton filled incandescent lamps," *Journal of IES*, April 1975, pp. 188-197.

This paper explained how the researchers developed 35 watt lamps to replace conventional 40 watt models, 54 and 55 watt lamps to replace conventional 60 watt models, 90 and 92 watt lamps to replace conventional 100 watt models, and 135 and 138 watt lamps to replace conventional 150 watt models. In each case, they were achieving comparable light output levels and lifetimes to the lamps they were replacing. They chose to change the shape and slightly reduce the size of the krypton models relative to conventional ones, because lower conduction-convection heat losses through the gas allow the bulb to be smaller without getting too hot. An additional advantage of this approach is that the smaller lamp volume would reduce the amount of krypton needed, while also helping consumers distinguish the more efficient krypton bulbs at a glance from conventional ones.

W.E. Thouret, H.A. Anderson, and R. Kaufman, "Krypton Filled Large Incandescent Lamps," *Illuminating Engineering*, April 1970, pp.231-240.

The abstract of this article is particular instructive:

> As krypton has become available recently at lower cost, the use of this gas can now be justified for regular service incandescent lamps up to 100-watt and for special service types. The obtainable efficacy or life improvements have been studied experimentally and theoretically. Performance data are presented for several lines of krypton-filled lamps for standard voltages between 40 and 100 watts. Application advantages of these lamps and possible future developments are discussed in conclusion.

A third source is noteworthy as well. The Illuminating Engineering Society of North America routinely updates and consolidates the body of reference information on lighting into a single volume known as the *IESNA Lighting Handbook: Reference and Applications*. The Ninth Edition of that reference, published in 2000, offers the following insights (page 6-9) into krypton fill gas:

> Inert gases are now preferred because they do not react with the internal parts of the lamp and because they conduct less heat than nitrogen. It was some years after the development of gas-filled lamps before argon became available in sufficient quantity and purity and at reasonable cost. Most lamps are now filled with argon and a small amount of nitrogen; some nitrogen is necessary to suppress arcing between the lead-in wires… Typical amounts of argon in use are: …95% for 120-V general-service coiled-coil lamps… Krypton, although expensive, is used in some lamps where the increase in cost is justified by the increased efficacy or increased life. Krypton gas has lower heat conductivity than argon. Also, the krypton molecule is larger than that of argon and therefore further retards the evaporation of the filament. Depending on the filament form, bulb size, and mixture of nitrogen and argon, krypton fill can increase efficacy by 7 to 20%. [the section concludes by citing the two Thouret papers above]

Industry representatives indicated during previous CEC hearings and informal meetings that a linear specification line (plotting wattage vs. lumens) for incandescent lamps would not save as much energy as PG&E suggested, since the manufacturers would choose to increase brightness at a given wattage rather than reduce wattage at a given brightness. In response to this comment, Ecos Consulting proposes a change to the shape of the Tier 2 specification lines that would specifically encourage wattage reduction in the most popular lamp models rather than light output increase. In brief, the new proposed specification lines increase efficacy requirements steadily within the range of wattages closely bracketing 40, 60, 75, 100, and 150 watts. Thus, manufacturers would face a significantly higher efficacy requirement if they wanted to sell a brighter 100 watt bulb, for example, than if they wanted to sell a 90 watt bulb with brightness equal to a conventional 100 watt model. No reasonable specification can entirely *prevent* manufacturers from selling brighter bulbs at equivalent wattage, but this one provides a very compelling incentive for manufacturers to do otherwise.

The net effect of this change is that the required efficacies vary from slightly less stringent to slightly more stringent than the original Tier 2 specification line. This can be seen in Figures 1, 2, and 3 where the new proposed Tier 2 line repeatedly crosses above and below the old one. As before, however, the specification lines are designed to ensure that existing models in each of the common wattage and light output ranges qualify. Likewise, generally each of the manufacturer's catalogs surveyed contributes at least two models to the list of qualifying products, so the proposed standards would not preferentially favor one manufacturer's technology over another's. Indeed, the purpose of adding projected krypton models to Figures 1, 2, 3, and 4 is to illustrate that adding a krypton fill gas to the most popular lamp models sold today would allow them to meet the proposed specifications. None of the discussion of krypton fill gas in this document should be construed as a proposal that the CEC require the use of krypton fill gas. Multiple design solutions are available to manufacturers to achieve higher efficacy. Krypton fill gas represents one of the more straightforward approaches to doing so, and one with promising cost effectiveness, but halogen fill gas and other filament solutions would be viable options for manufacturers to consider as well.

Additionally, Figure 1 illustrates that most enhanced spectrum models sold today cannot meet the recently adopted Tier 1 standards for soft white lamps nor either of the proposed Tier 2 standards for that category. Therefore, we propose a new standard specifically for enhanced spectrum lamps (Figure 4). One model recently introduced by Westinghouse already qualifies. Engineering analysis confirms that many others would qualify with the addition of krypton.

The California Energy Commission may also wish to consider minimum lifetime requirements for general service incandescent lamps in order to discourage manufacturers from achieving high efficacy simply by tuning lamps for short lifetimes. Plausible minimums would be at least 1,000 hours of lifetime for lamps ranging from 25 to 60 watts, and at least 750 hours for lamps ranging from more than 60 watts to 150 watts.

Overall, we anticipate energy savings resulting from the revised Tier 2 proposal to be somewhat higher than from the original Tier 2 proposal, primarily because a smaller percentage of existing models qualify today. More importantly, this proposal increases the *certainty* associated with those savings estimates.

Figure 1: Soft White Light Bulbs, Including Enhanced Spectrum Light Bulbs

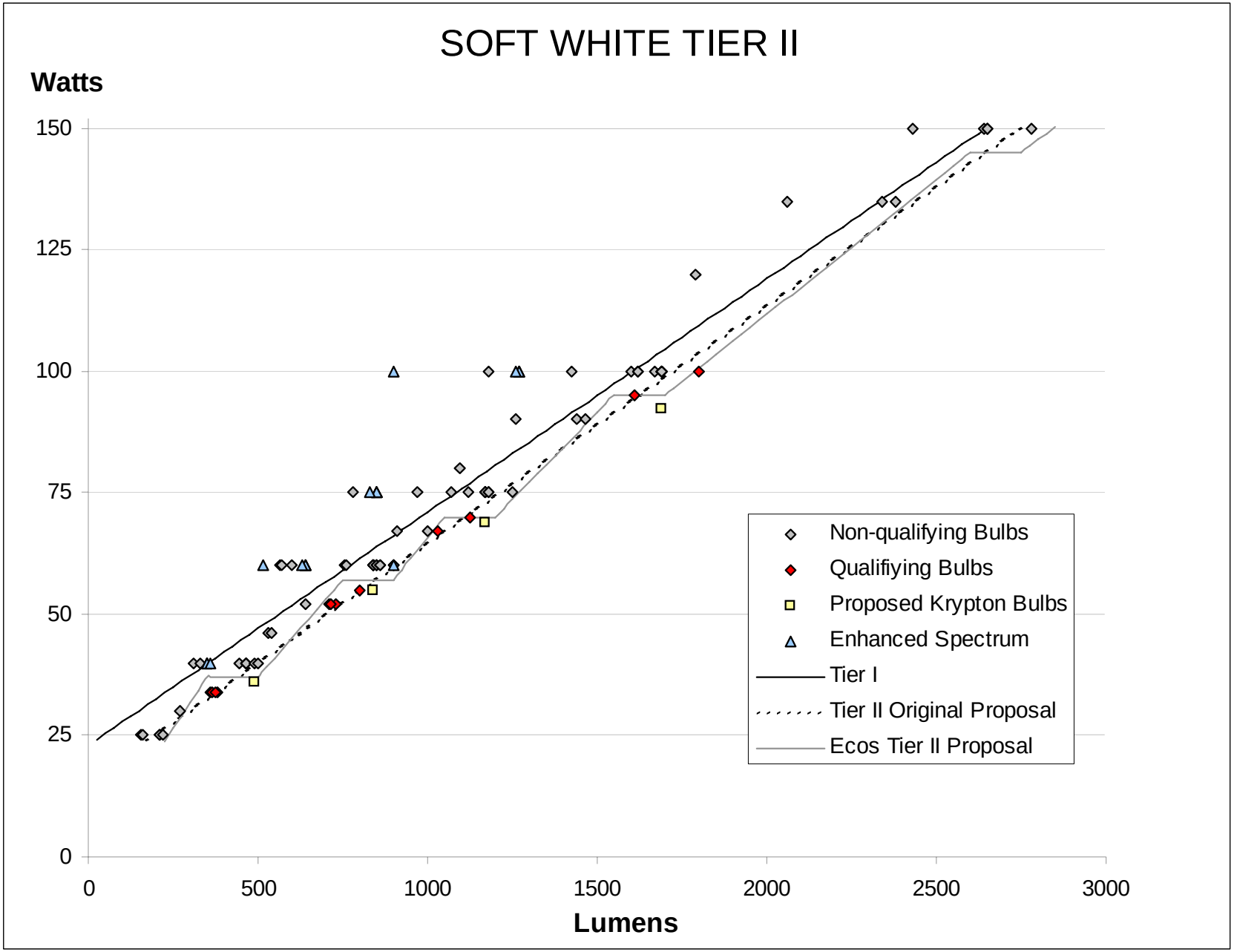


Figure 2: Soft White Light Bulbs

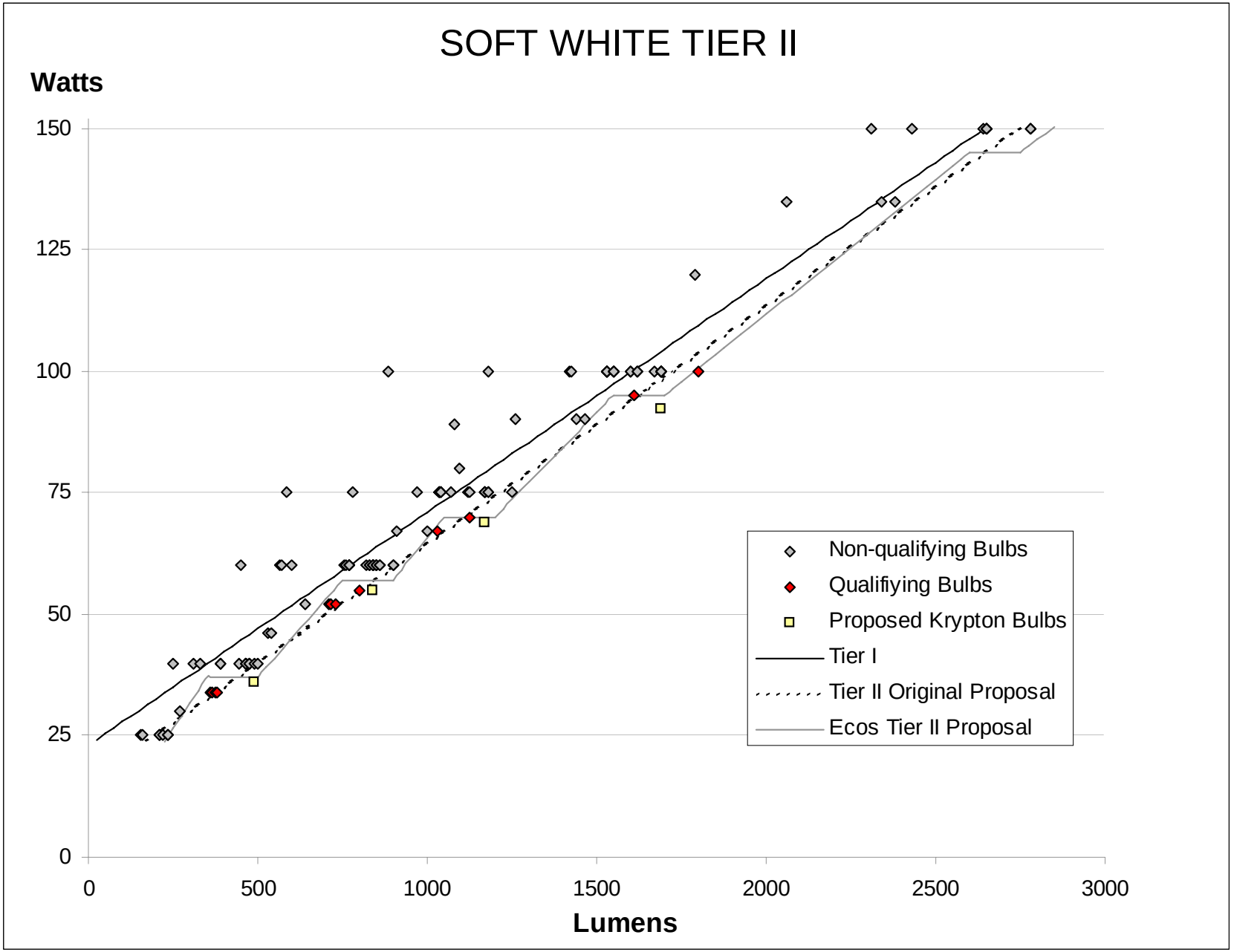


Table 1: Qualifying Soft White Light Bulbs

Manufacturer	Description	Bulb Shape	Product #	Ordering Code	Volts	Life (hrs)	Power (watts)	Light output (lumens)
General Electric	Watt-Miser® Plus-Diffuse Coating.	A19	13009	40A/34WMP/99	130	2500	34	360
General Electric	Watt-Miser®-Diffuse Coating	A19	12620	40A/34WM	130	2000	34	365
General Electric	Watt-Miser®-Diffuse Coating	A19	12612	40A/34WM	120	2000	34	380
General Electric	Watt-Miser®-Diffuse Coating	A19	12623	60A/52WM	130	1000	52	710
General Electric	Watt-Miser®-Diffuse Coating	A19	12615	60A/52WM	120	1330	52	730
General Electric	Soft White, Miser®	A19	11904	55A/SW/MI 48PK	120	1000	55	800
General Electric	Watt-Miser®-Diffuse Coating	A19	12617	75A/67WM	120	1000	67	1030
General Electric	Soft White Miser	A19	11905	70A/SW/MI 48PK	120	750	70	1125
General Electric	Soft White Miser	A19	11906	95A/SW/MI 48PK	120	750	95	1610
Sylvania	Soft White Energy Saver	A19	11391	40A/34/W/ES/4PK	120	1500	34	375
Sylvania	Soft White Energy Saver	A19	11392	60A/52/W/ES/4PK	120	1000	52	715
Westinghouse	Soft White	BT15	36822	100BT15/H/SW/CD	120	2000	100	1800

Figure 3: Frosted and Clear Bulbs

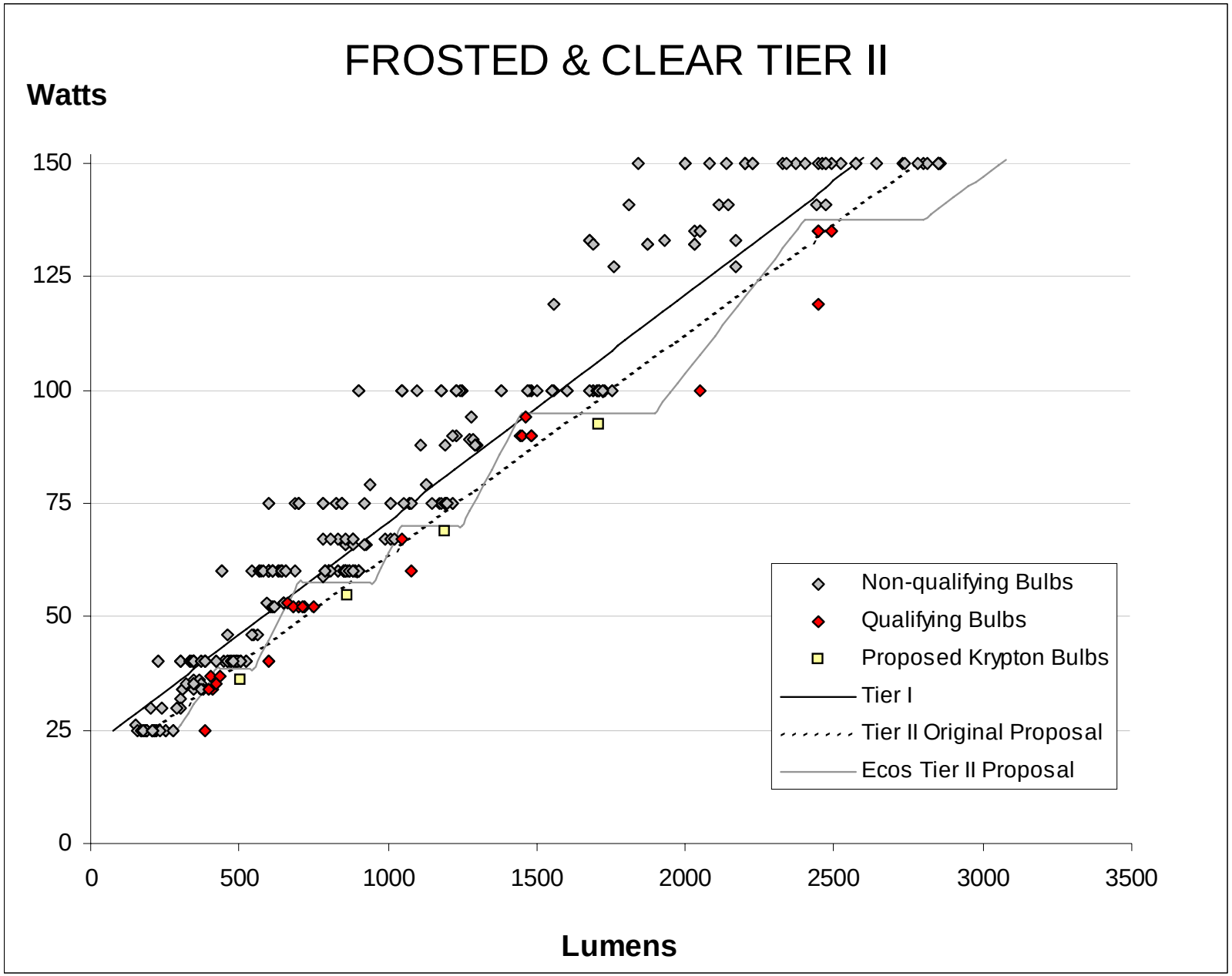
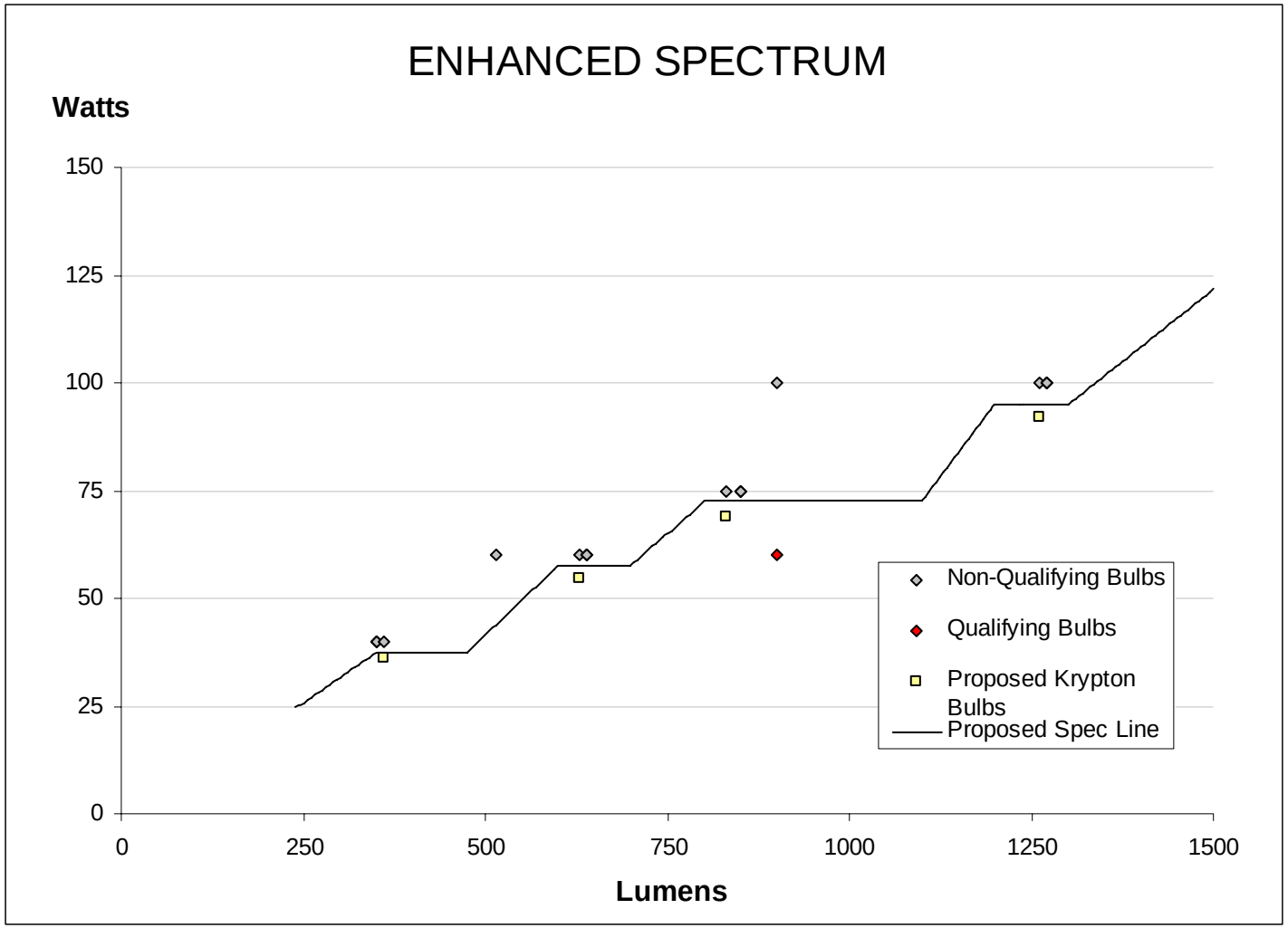


Table 2: Qualifying Frosted or Clear Light Bulbs

Manufacturer	Description	Bulb Shape	Product #	Ordering Code	Volts	Life (hrs)	Power (watts)	Light output (lumens)
Feit	Frost 24-Pack, 14400 Hours			40A/XL/MP-130	130	5000	40	600
Feit	Clear 24-Pack, 14400 Hours			40A/CL/XL/MP-130	130	1000	40	600
General Electric	Watt-Miser®-Clear	A19	13555	60A/52WM/CL	130	1000	52	720
Philips	Frost Econ-o-Watt	A19	22235-6	40A-34A/EW	130	1500	34	400
Philips	Frost Extended Service	A19	37400-9	40A/99	120	5100	37	405
Philips	Frost Econ-o-Watt	A19	22234-9	40A-34A/EW	120	1500	34	410
Philips	Clear	A19	37399-3	40A/CL	120	2550	37	435
Philips	Clear	A19	37522-0	60A/CL	120	2830	53	665
Philips	Frost Econ-o-Watt Extended Service	A19	22239-8	60A-52A/EW	130	1000	52	680
Philips	Frost Econ-o-Watt	A19	22237-2	60A-52A/EW	120	1000	52	700
Philips	Frost Econ-o-Watt	A19	22243-0	100A-90A/EW	120	750	90	1445
Philips	Frost	A21	28171-7	100A21	120	1280	94	1463
Philips	Frost	A21	34803-7	100A	120	1000	100	2050
Philips	Frost Econ-o-Watt	A21	28175-8	150A-135A/EW	130	750	135	2490
Sylvania	Standard Frost	A19	10449	25A	120	1000	25	385
Sylvania	Clear Excel-Line SS	A19	11053	40A/CL/99/XL	120	2500	35	420
Sylvania	Standard Frost Super Saver	A19	11380	60A/52/SS	130	1000	52	710
Sylvania	Standard Frost Super Saver	A19	11376	60A/52/SS	120	1000	52	750
Sylvania	Standard Frost Super Saver	A19	11377	75A/67/SS	120	750	67	1050
Sylvania	Standard Frost Super Saver	A19	11396	100A/90/W/ES/4PK	120	750	90	1450
Sylvania	Standard Frost Super Saver	A19	11378	100A/90/SS	120	750	90	1480
Sylvania	Standard Frost Super Saver	A19	11382	100A/90/SS	130	750	90	1480
Sylvania	Standard Frost Super Saver	A21	12820	150A21/135/SS	120	750	135	2450
Sylvania	Standard Frost Super Saver	A21	12863	150A21/135/SS	120	750	135	2450
Sylvania	Standard Frost Super Saver	A21	12863	150A21/135/SS	120	750	119	2450
Westinghouse	Clear	BT15	36819	60BT15/H/CD	120	3000	60	1080

Figure 4 – "Enhanced Spectrum" Bulbs



Qualifying Model Information

Manufacturer	Description	Bulb	Product #	Ordering Code	Volts	Watts	Lifespan (hrs)	Lumens
Westinghouse	Natural Lite	BT15	3411	60BT15/H/RNL/CD	120	60	2000	900